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APPLICATION

OF

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FOR

UNITED STATES LETTERS PATENT

ON

(U) FAR INFRARED TANDEM LOW ENERGY OPTICAL POWER LIMITER DEVICE

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(U) FAR INFRARED TANDEM LOW ENERGY OPTICAL POWER LIMITER DEVICE

(U) The invention described herein may be manufactured, used, and licensed by the U.S. Government for governmental purposes without the payment of any royalties thereon.

(U) <u>BACKGROUND OF INVENTION</u>

(S) **Field** - The present invention relates to an optical power limiter device for protecting thermal sensors against threat incoming radiation, and especially to providing a plurality of optical power limiters in tandem between window substrates with each limiter having a progressively lower switching threshold temperature to the incoming radiation so that the last limiter is usually the first to switch on by increasing temperature and reflect back the radiation for a second pass through the other limiters and quickly raise their temperatures to threshold level in which the tandem of limiters essentially switch on sequentially to provide increase in optical density for the device.

(S) **Prior Art** – It is highly desirable to protect sensitive thermal sensors against threat laser radiation which disables the performance of the sensors by jamming or damaging components. Some of the requirements for optical power limiter device are that it be passive and self-activated, broadband between say 7um to 12um, a field of view of more than 20°, low thermal switching threshold, large optical density in the switched state, and highly transmissive in the unswitched state.

(U) Devices exist that meet some of these requirements. For example, a chalcogenide optical power limiter or a vanadium dioxide (VO_2) optical power limiter used separately can meet some of these requirements, but not all of them. The chalcogenide device has a higher switching threshold, a lower damage threshold, and a lower transmission than the requirements. The VO_2 device has a low switching threshold, but also has the undesirable low damage threshold and low transmission. Germanium optical power limiters undergo thermal runaway starting at about 75°C where the absorption coefficient increases rapidly.

(U) Combinations of the above noted optical power limiter materials as in the present device results in an acceptable device with increased damage threshold, improved switching threshold, and improved optical density which protect the sensors and other optical components more effectively.

(U) **SUMMARY OF THE INVENTION**

(U) The spirit of the present invention is presented in two separate embodiments, but it is understood that the scope of the invention is not limited to these embodiments. The first embodiment is comprised of the following in order, an input antireflective coating layer, an input window substrate layer, a plurality of layered optical power limiters, namely layers of chalcogenide, germanium and VO_2 having progressively lower switching threshold temperatures, an output window substrate layer, and an output antireflective coating layer. The second embodiment is the same as the first embodiment but has an extra layer of VO_2 deposited between the input antireflective coating and input window substrate layers.

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(S) Operationally, when the first embodiment receives a low amount of input radiant energy through the input antireflective coating and input window substrate layers all of the plurality of optical power limiters absorb the energy and have a rise in temperature. The VO_2 layer limiter is switched on first at the lowest self-activated temperature causing reflection of any subsequent input energy back to the germanium layer limiter for further absorption therein and if enough subsequent input energy is passed back through the germanium layer limiter it undergoes thermal runaway, i.e. is switched on, at a temperature only slightly more than the switching threshold temperature of the VO_2 layer limiter. The remainder of the input energy reflected from the VO_2 layer limiter after the germanium layer limiter is switched is further absorbed by the chalcogenide layer limiter which may be switched so that all of said plurality of optical power limiters are essentially switched on sequentially. If the input energy is greater than in the last illustration the higher switching threshold temperature chalcogenide layer limiter will self activate first and absorb the input energy and protect the germanium and VO_2 limiters.

(S) The second embodiment is a slight variation of the first embodiment and is comprised of adding a second layer of VO_2 to the first embodiment between the input antireflective coating layer and the input window layer. Operationally, the second layer of VO_2 limiter will heat up very quickly with higher input energy and will switch on to reflect the subsequent higher input energy before the input energy even gets to the input

~~(S)~~ window. The purpose of this embodiment is to limit the energy to the remainder of the downstream optical power limiters when a higher input radiation than what is required for the switching of the chalcogenide layer limiter enters the device. Another advantage of the second embodiment over the first is that at a high threat radiation level, the radiation is reflected rather than absorbed thereby protecting the device.

(U) The exact thicknesses of each of the layers is dictated by the transmission and the thermal properties required of each of the layers individually. Some of the requirements are that the total transmission in the unswitched state of the device exceed a certin value, the switching threshold be low enough to be useful, and concept of the multilayered device be effective to limit the threat radiation transmitted through the device. The materials used for the input and output window substrates are preferably zinc selenide or germanium at a thickness on the order of one millimeter or less determined by the structural strength required for the fabrication and the handling of the device. The thickness of the plurality of optical power limiter layers are less than 50um for the chalcogenide layer, less than 100um for the germanium layer, and less than 5um for the VO_2 layer.

(U) The damage threshold of the device is improved by the window material being made of zinc selenide or germanium since these materials have higher damage thresholds than the VO_2. The damage threshold of the device may be further improved by putting a diamond-like carbon coating layer on the window layers. The germanium optical power limiter between the chalcogenide and VO_2 layers has the added advantage that it may facilitate their bonding.

(U) **BRIEF DESCRIPTION OF THE DRAWINGS**

(U) Figures 1A through 1D illustrate schematically the switching sequence of the first embodiment; and

Figures 2A through 2E illustrate schematically the second embodiment.

(U) **DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS**

(U) Refer to Figures 1A through 1D for an explanation of one embodiment of the device. Figure 1A illustrates the device in the unswitched highly transmissive state where the output radiation energy 6B is generally more than 80% of the input radiation energy 6A as long as 6A is below a threshold level. That is, as long as 6A is below the threshold level, the plurality of tandem optical power limiter layers 14, 16, and 18 will not increase in temperature to the self-activated state, i.e. switch on from the transmissive to either the reflective or absorptive states. An input antireflective coating layer 10A and input window substrate layer 12A are on the input side of the chalcogenide layer 14, the germanium layer 16, and the VO_2 layer 18. At the output of layer 18 are the output window substrate layer 12B and output antireflective coating layer 10B.

(U) Figure 1B illustrates schematically what happens when the input radiation energy, perhaps from an adversary intending to damage the thermal sensors, is increased above the threshold level. Number 18S is used to indicate that the VO_2 layer 18 is now in a switched condition caused by absorption of the higher input energy and increase of temperature to 68° C. The input energy 6A is reflected back from 18S as reflected energy 6C through layers 16, 14, 12A, and 10A instantaneously. Meanwhile, Figure 1C illustrates that the germanium layer 16 has absorbed the reflected energy from 18S and

(U) instantaneously undergoes thermal runaway at 75° C and is switched on as represented by 16S. Figure 1D illustrates the situation when the chalcogenide layer 14 has also instantaneously switched on as represented by 14S by the radiation and thermal energy reflected back from layer 16S. At this time all three of the plurality of layers 18S, 16S, and 14S are in the switched condition which has drastically increased the optical density of the device, has increased the damage threshold of the device at least to the higher level of the chalcogenide layer 18, and has switched the device on at the lowest switching threshold of the VO_2 layer 18.

(U) Refer now to Figures 2A through 2E for an explanation of the second embodiment of the device. Figure 2A illustrates the device in the unswitched high transmissive state where 6B is still more than 80% of 6A as in the first embodiment. A second layer of VO_2, represented by 20, is however placed between 10A and 12A. At the lower input energy levels the second embodiment will function the same as the first embodiment. That is, the switching on of all layers 18, 16, and 14 to fully increase the optical density of the device as controlled by the plurality of optical limiter layers could have actually been partially switched if the input energy was slightly above the threshold level. Stated another way, only 14 and 16 may have switched. The adding of a second layer of VO_2 between 10A and 12A is to protect the thermal sensors at higher input radiation energy than was required to switch on the chalcogenide layer 14S in the above illustration where all three 18S, 16S, and 14S were self-activated. This assumes that the input radiation is focused on VO_2 layer 18 and is thus more wide spread on VO_2 layer 20.

(U) Figures 2B, 2C, and 2D illustrate respectively the switching of 18S into a reflective state and 16S and 14S into absorptive states. Figure 2E illustrates what could happen by placing the second layer of VO_2 between 10A and 12A when a still higher input radiation energy 6A enters the device. The second VO_2 layer 20 will self-activate first into the switched state 20S. Layer 20S will immediately reflect the incoming radiation 6A back as reflected radiation 6C and will reflect subsequent radiation to protect the downstream plurality of optical power limiter layers 14, 16, and 18. Advantages to using the second embodiment is that the device itself is protected from damage when operated in a high threat laser radiation environment. That is, damaging radiation is reflected away from the device immediately rather than absorbed in layers 18, 16, and 14 or the other layers.

(U) Modifications and variations of the present invention are possible in light of the above teachings. It is therefore to be understood that within the scope of the appended claims the invention may be practiced otherwise than as specifically described.

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